A BELT-LIKE SUPERFINE FILM FABRICATED BY THE BUBBLE-ELECTROSPINNING

by Hao DOU, Hong-Yan LIU, Ping WANG, and Ji-Huan HE*

a National Engineering Laboratory for Modern Silk, College of Textile and Clothing Engineering, Soochow University, Suzhou, China
b School of Fashion Technology, Zhongyuan University of Technology, Zhengzhou, China

Short paper
DOI: 10.2298/TSCI1305508D

A belt-like superfine film is prepared via the bubble-electrospinning from an aqueous silk fibroin solution. The morphology of film structures is characterized by the scanning electron microscope. The average width of the film is about one micrometer and the thickness is about 377 nanometers.

Key words: bubble-electrospinning, silk fibroin, belt-like structure

Introduction

In recent years, much attention has been paid to the electrospinning method for the reason that it can make superfine fibers in the quickest and simplest way and lots of applications benefit from the large specific surface area and high porosity of the electrospun nanofibers [1]. As a challenging method, the bubble-electrospinning [2] greatly boosts output and improves spinnability by overcoming the surface tension of a polymer bubble [2].

Silk fibroin has been extensively studied due to its distinctive properties such as biocompatibility, degradability, and excellent mechanical properties [3]. In order to avoid the common use of toxic solvents like hexafluoro-2-propanol (HFIP) and formic acid, different kinds of approaches were suggested by concentrating aqueous silk fibroin solution (>25%) [4], adjusting pH value [5], and incorporating silk fibroin with polyethylene oxide (PEO) [6].

In this research, the bubble-electrospinning is adopted to fabricate superfine silk fibroin films with deionized water as a solvent and a flat belt-like film is obtained successfully from such an aqueous solution at a relatively low concentration.

Experimental part

Raw silk was degummed three times with 0.5% (w/w) Na₂CO₃ solution at 100 °C for 30 minutes and then washed with distilled water. Degummed silk fibroin (SF) was dissolved in 9.3 mol/L LiBr solution. After dialysis in cellulose tubular membrane (molecular weight cutoff = 8000~14000, Sigma, USA) against distilled water for 3 days and filtration, the final SF aqueous solution with concentration about 3.5% was obtained.

The aqueous SF solution was heated and concentrated at temperature 45 °C in order to acquire a solution with 15% concentration. Then the prepared SF solution was carried out by a bubble electrospinning apparatus developed in our laboratory under voltage of 12 kV and the distance between nozzle and collector was 10 cm. The schematic was shown in fig. 1.

* Corresponding author; e-mail: hejihuan@suda.edu.cn
The morphology of electrospun films were observed with the scanning electron microscopy (SEM, S-4800, Hitachi, Tokyo, Japan) at 20 °C and 60% relative humidity.

**Results**

According to the SEM photographs shown in fig. 2, it can be observed that belt-like superfine films with smooth surface were produced. The average width was $1.17 \pm 0.12$ micrometers and the thickness was $377.67 \pm 95.62$ nanometers. Many researchers [7-9] considered that the elongation of the jet and evaporation rate of the solvent changed the shape and the charge of the jet, which determined the final morphology. The belt-like morphology may result from the presence of a thin bubble film generated from rupture of polymer bubbles. Interestingly, a 3-D spiral superfine ribbon was observed, which indicated the instability behavior of the charged jets [10, 11].

**Conclusion**

Silk fibroin nanofibers have been explored for wide applications, such as high-performance filters and biomaterial scaffolds for vascular grafts or wound dressings. Bubble-electrospun films without any chemical solvents provide benefits due to avoiding toxicity toward organisms. Furthermore, since the morphology of a material plays a significant role in properties and applications, belt-like superfine films would open new directions in the future.

**Acknowledgment**

The work is supported by Priority Academic Program Development of Jiangsu Higher Education Institutions (PAPD), National Natural Science Foundation of China under grant No. 61303236 and No.11372205 and Project for Six Kinds of Top Talents in Jiangsu Province under grant No. ZBZZ-035, Science & Technology Pillar Program of Jiangsu Province under grant No. BE2013072.

**References**

Dou, H., et al.: A Belt-Like Superfine Film Fabricated by the Bubble-Electrospinning

THERMAL SCIENCE, Year 2013, Vol. 17, No. 5, pp. 1508-1510


